Mitigating Terrorist Attacks and Earthquake Risk

International Building Code Revisions Can Provide Solutions

By James Lefter, P.E.

The United States has almost universally adopted the International Building Code (IBC 2009) that includes provisions for design against geographical hazards (snow, wind, flood and earthquake) and fire. There are no blast resistant structural design provisions in the IBC. In the United States, recent acts of terrorism against The World Trade Center, the Pentagon and the Murrah Building in Oklahoma City, had precipitated disastrous consequences. The Chilean earthquake caused extensive nonstructural damage in an area of weak ground shaking. In contrast, the U.S. Embassy facility's performance in the 2010 Port au Prince earthquake demonstrated that IBC requirements for Seismic Design Categories D or above can mitigate seismic damage. These code provisions can also mitigate terrorist blast attacks. They should be applied to all important buildings.

Building Codes set minimum requirements to safeguard the public health, safety and general welfare and are legally enforceable by the adopting jurisdiction. The IBC seismic design provisions are based on occupancy category and seismic microzonation maps. For economic reasons, the maximum earthquake ground motion for any site has a probability of exceedance of 2 percent in 50 years. The specific requirements in the IBC against terrorist attacks are for standby power, risers for automatic sprinkler systems, stair tower changes, and improved characteristics for sprayed on fire resistant materials. There are none for blast resistant structural and nonstructural design.

The IBC assigns buildings to Seismic Design Categories from A, the lowest, to F, the highest. Special details for frames and shear walls are required only for Seismic Design Categories D and above. These details increase the cost of construction in high seismic hazards areas, but this increase is only a few percent of total construction cost (ATC-57). These details can also mitigate terrorist attacks.

Murrah Building

The April 19, 1995, blast collapsed half of the 9-story reinforced concrete Murrah Federal Building, killing 168 people. Four columns were destroyed; one directly due to blast, and three due to a combination of blast and the loss of lateral support. Like most U.S. buildings, the Murrah Building met the then current building code requirements and was conventional in design and construction. It had no supplementary ductility or toughness, or seismic resistance that might have mitigated the blast force (Corley 1998). Studies of strengthening schemes showed that special moment frames and perimeter shear walls could have effectively reduced direct blast-induced damage (Hayes 2005).

World Trade Center Towers

On September 11, 2001, terrorists flew jetliners into the Twin Towers of the World Trade Center. Although seven buildings in the complex were destroyed, this article focuses on the Twin Towers attacks. The 110-story Towers buildings were office buildings of almost identical structural design as vertical structural steel cantilever tubes. The planes penetrated the Towers buildings and exploded, causing significant damage and extensive fires. Designed to resist the impact of a jetliner crash, the Towers survived the jetliners crashes, but collapsed due to the fires that followed (Miamis 2009), killing 2752 people, including firefighters.

The impacts destroyed parts of the structural systems, dislodged and damaged the structures' fire protective insulation, disabled the fire sprinkler systems, demolished interior partitions, breached exterior walls and floors, knocked all elevators out of service, and blocked exit stairwells. The fires spread through several stories at the levels of impacts, uncontrolled because sprinkler systems were broken; and the partially unprotected steel structures, exposed directly to the fires, collapsed. Almost all occupants above the impact stories perished.

The probability of extensive collateral and fire damage from an airliner crash was foreseen (Seattle Times 1993) but not addressed directly by the designers. The Towers' structural engineers had no responsibility for fire protective design; that was the responsibility of the architects (NIST NCSTAR 1).

The Port Authority of New York and New Jersey adopted the 1968 Edition of the New York City Building Code for the WTC design. NIST identified at least two code violations that may have contributed to the disaster (NIST NCSTAR 1):

- The code required a minimum of four independent means of egress from the observation deck at the top of each building. Only three were provided.
- The design for both buildings specified a 0.5-inch thickness of sprayed-on fire resistant insulation on floor truss members in order to meet a 2-hour fire endurance rating. NIST fire tests for 0.75-inch insulation received a rating of 2-hours; the 0.5-inch insulation thickness received a rating of 45 minutes.

Chile Earthquake Feb 2010

Current Chilean building codes require modern earthquake resistant design and construction. The M 8.8 Chilean earthquake of February 27, 2010, generated strong ground shaking throughout Chile. In Concepción, near the epicenter, about 20 percent of buildings over 15 stories in height were damaged beyond repair. In Santiago, where there was relatively weaker ground motion, buildings under construction in an office development project were largely undamaged structurally. But there was extensive damage to many of the nonstructural components (ceilings, interior partitions, heating and ventilating equipment, ducts and piping). There would have been many casualties if the earthquake had occurred during the day (Yanev, 2010).

Haiti Earthquake

Haiti is a high risk earthquake area, but has no effective building code. The 2010 Port au Prince earthquake destroyed almost every inhabitable structure in the area, killing over two hundred thousand people and leaving more than a million homeless.

However, the new Port au Prince U.S. Embassy facility, completed in 2008, had only cosmetic nonstructural damage and remained fully functional after the earthquake.

Since 1998, there had been over 150 attacks on US Embassies, prompting the State Department to begin a program to design its facilities against blast attacks as well as conventional hazards. The design standards are based on the IBC, but with specific seismic site studies.

Seismic Design is the Key to Blast Mitigation

To mitigate against terrorist attacks, buildings must be able to resist blast forces as well as the traditional hazards. Blast-resistant design limits damage to confined areas. Although strength and stiffness are important, the keys to surviving seismic and blast forces are energy dissipation and ductility. Special moment frame design significantly increases the toughness of structures subjected to catastrophic loadings from blast as well as from major earthquakes (Corley 1998). Shear walls, especially perimeter walls, designed and detailed to resist high seismic forces, are also effective in reducing blast and progressive collapse (Hayes 2005). Design details are in the IBC but are required only for Seismic Design Categories D and higher.

Architectural, mechanical, and electrical components should be braced to resist the structure's strong motions under blast and seismic forces. Again, design details are in the IBC but are required only for Seismic Design Categories D and higher.

Summary and Conclusions

The Murrah Building collapsed immediately after the terrorist truck bomb exploded. Typical of most buildings in the U.S., it had no supplementary ductility or toughness, or seismic resistance, that might have mitigated the blast force.

The terrorist attacks on the World Trade Center Towers caused significant damage, extensive fires, and eventual collapse. The original building designs provided fire protection and fire suppression systems, smoke and fire partitions, smoke and fire alarms, HVAC systems for smoke control, and communication systems. These were installed in the Towers at great expense in the initial construction, but were generally unavailable after the attacks because they were not braced against strong motion. Extensive nonstructural damage occurred during the Chilean event in buildings designed as seismic resistant.

The U.S. Embassy facilities' performance in the Port au Prince earthquake demonstrated that IBC structural and nonstructural provisions required for Seismic Design Categories D or above can mitigate seismic disasters. These code provisions can be required for all important buildings at little additional construction cost while providing protection against terrorist attacks.

These examples demonstrate the need for:

- Structural strength, ductility, and energy dissipating details for all important structures.
- Appropriate bracing for architectural, mechanical and electrical components.
- Design and construction meeting all building code requirements.
- Structural engineers considering the impact on structure stability if the fire protection is compromised.

Recommendations

1) Design all important structures in Occupancy Classes II, III, and IV to meet all requirements of IBC Seismic Design Category D, or higher as appropriate.
2) Design bracing for permanent nonstructural components of all structures in Recommendation 1 to meet requirements of IBC Seismic Design Category D, or higher as appropriate, using a Nonstructural Component Importance Factor I_p of 1.5.
3) Require an independent Peer Review of the design.
4) Assign responsibility for fire protection of structural members to the structural engineer of record.

Some may assume that the cost of implementing these recommendations is too high. This article reports that we may choose either to implement them efficiently during design and construction at a marginal cost or to pay dearly later in lives, chaos and very high dollar costs. The Federal Government now requires all of its buildings to be designed to resist blast attacks as well as conventional hazards. In the meantime, all other schools, hospitals, and public buildings are vulnerable to terrorist attack. Spurred by the Haiti disaster and the terrorist threat, IBC should close these gaps immediately.▪

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